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Kato et al.

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(54) **LIGHT SOURCE DEVICE AND MANUFACTURING METHOD THEREOF**

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G02B 7/02 (2006.01)

(52) **U.S. Cl.** **347/242**; 347/257; 359/819

(58) **Field of Classification Search** 347/230, 347/241, 242, 244, 256–258; 359/819–830, 359/641, 694
See application file for complete search history.

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(57) **ABSTRACT**

A light source device includes: a semiconductor laser; a coupling lens; a holder; and a photopolymerizable resin. The coupling lens converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side. The holder holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser. A part of the photopolymerizable resin is provided between the outer peripheral surface of the coupling lens and the holder and another remaining part of the photopolymerizable resin protrudes from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, the photopolymerizable resin being cured to fix the coupling lens on the holder.

11 Claims, 4 Drawing Sheets

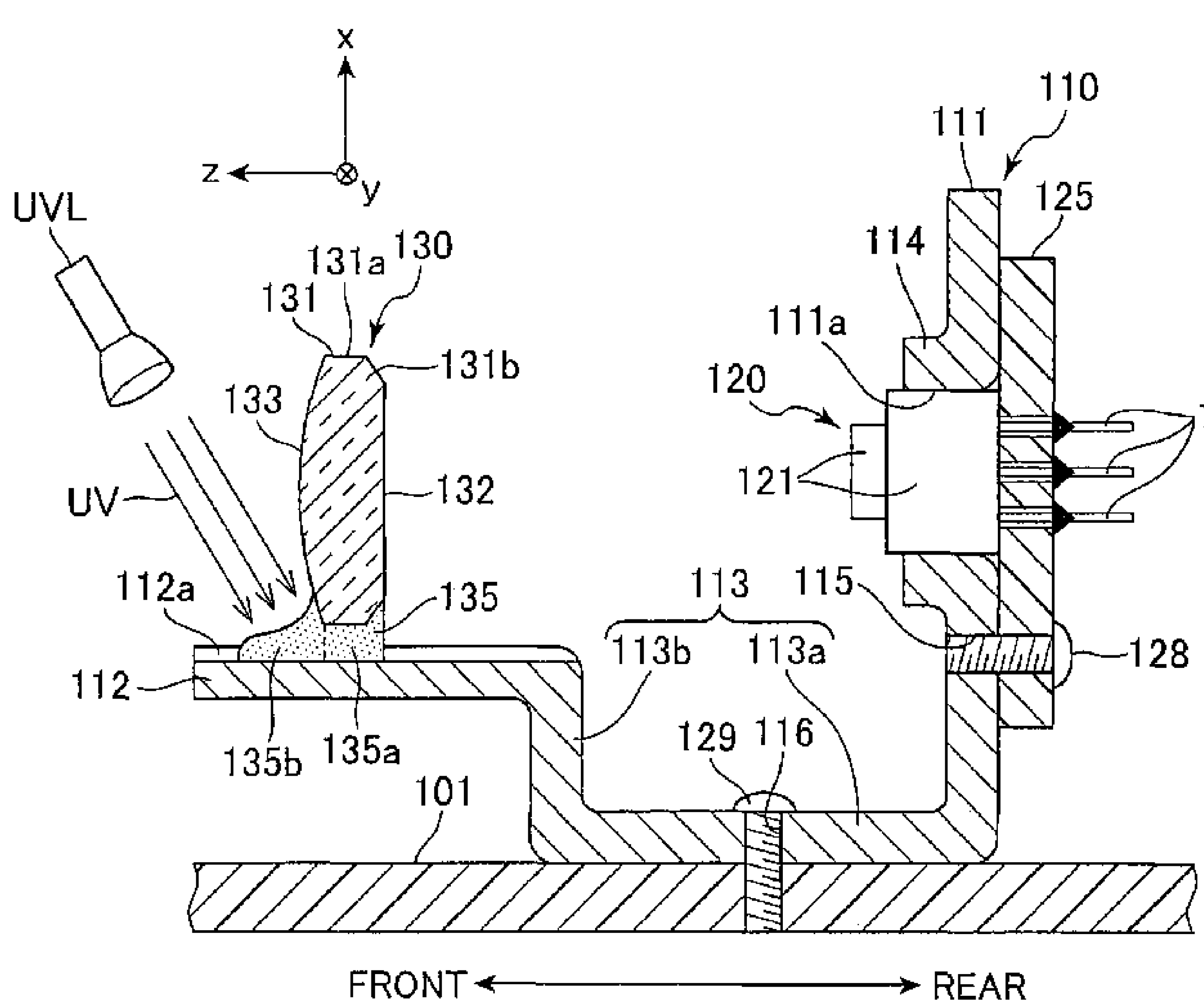

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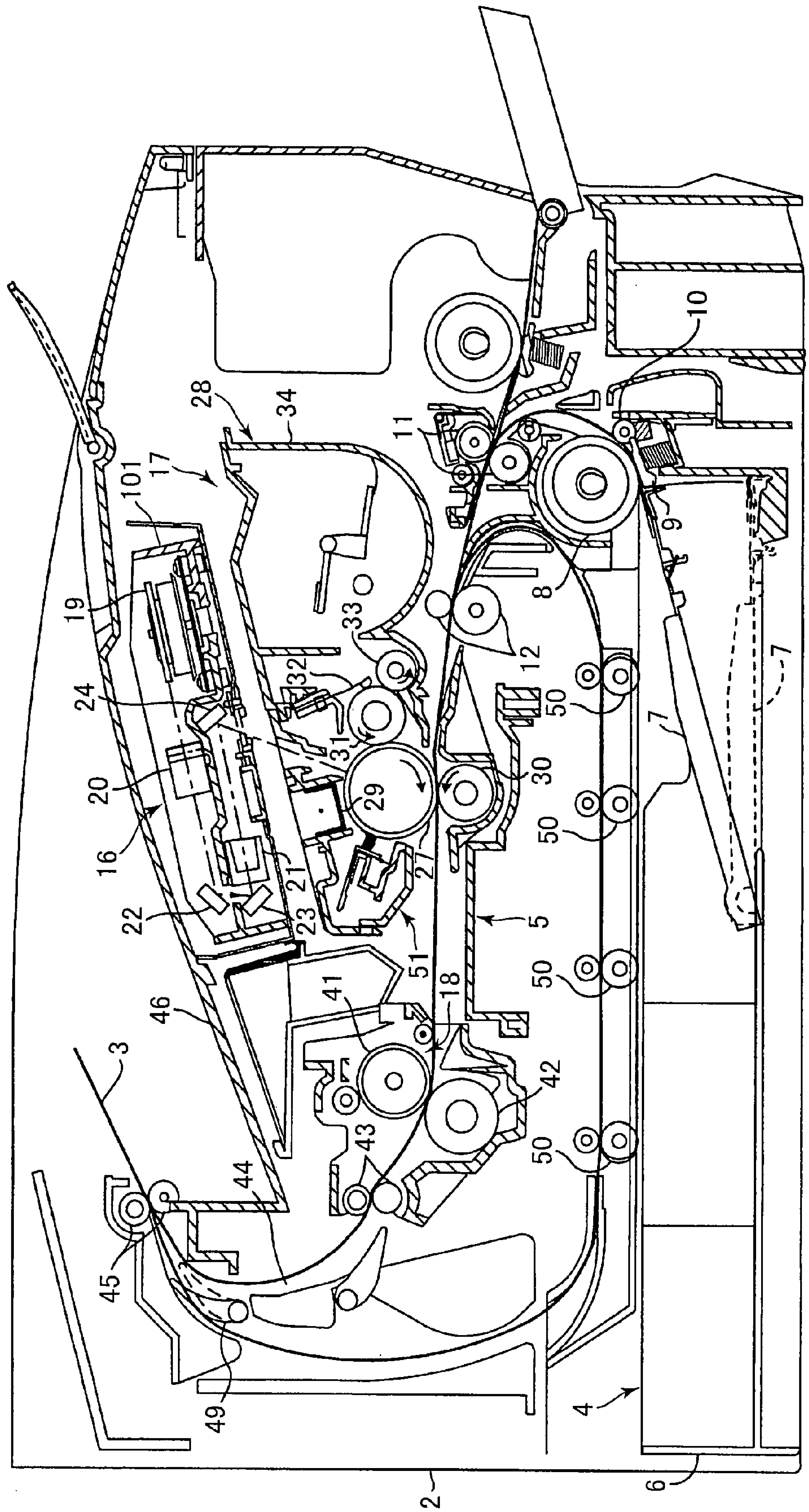
FIG.1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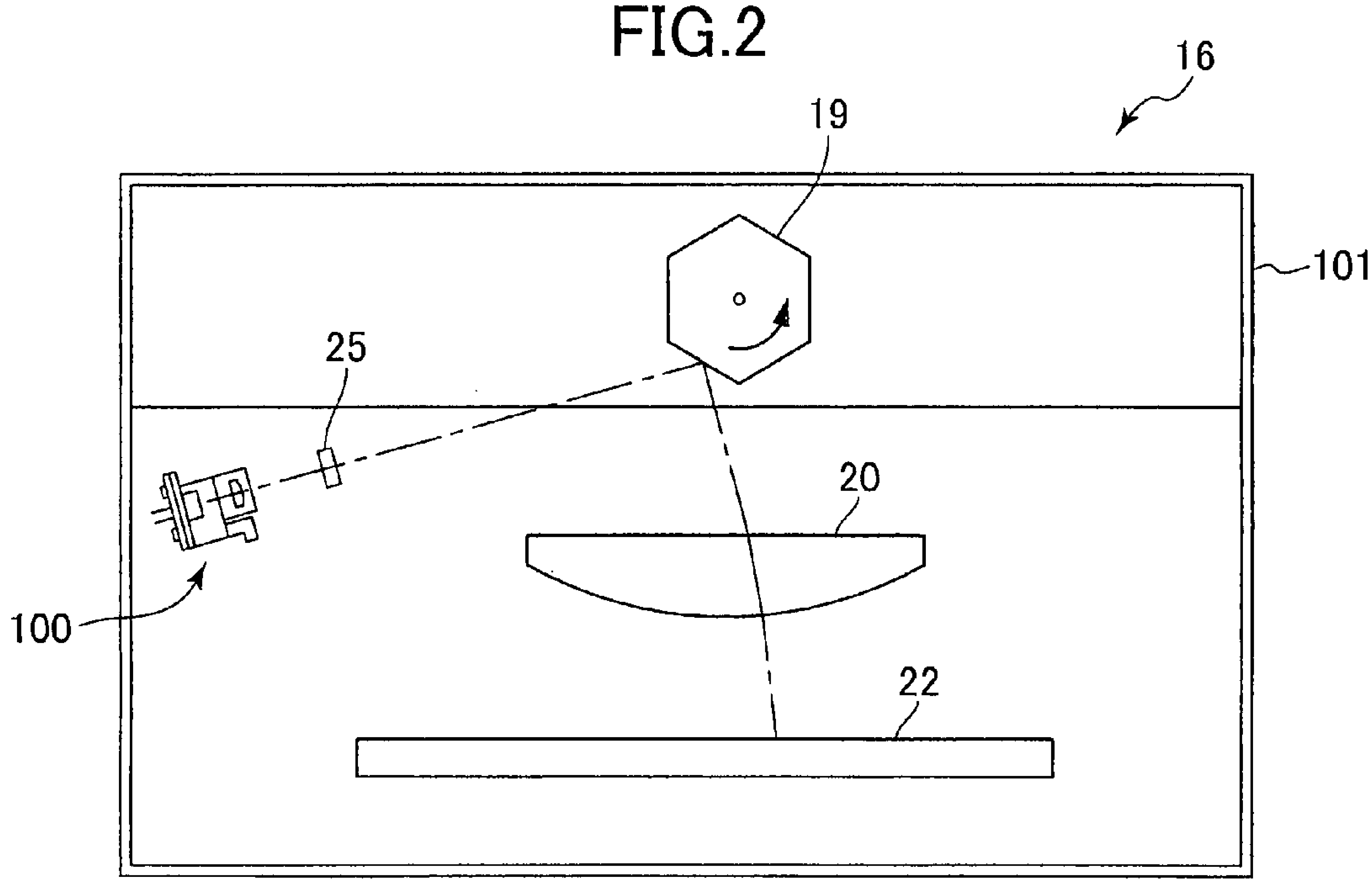
51
101

FIG.2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100
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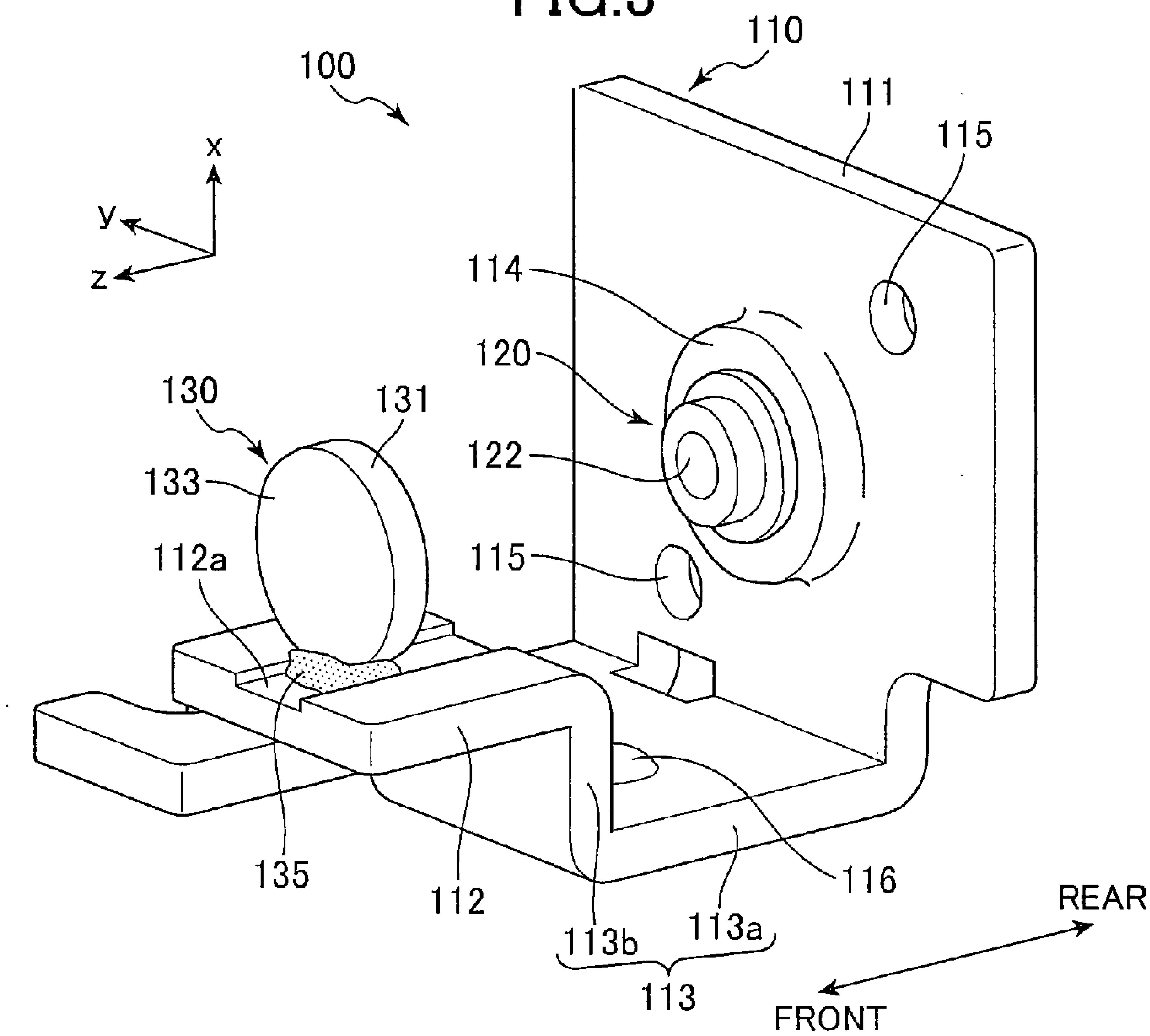
FIG.3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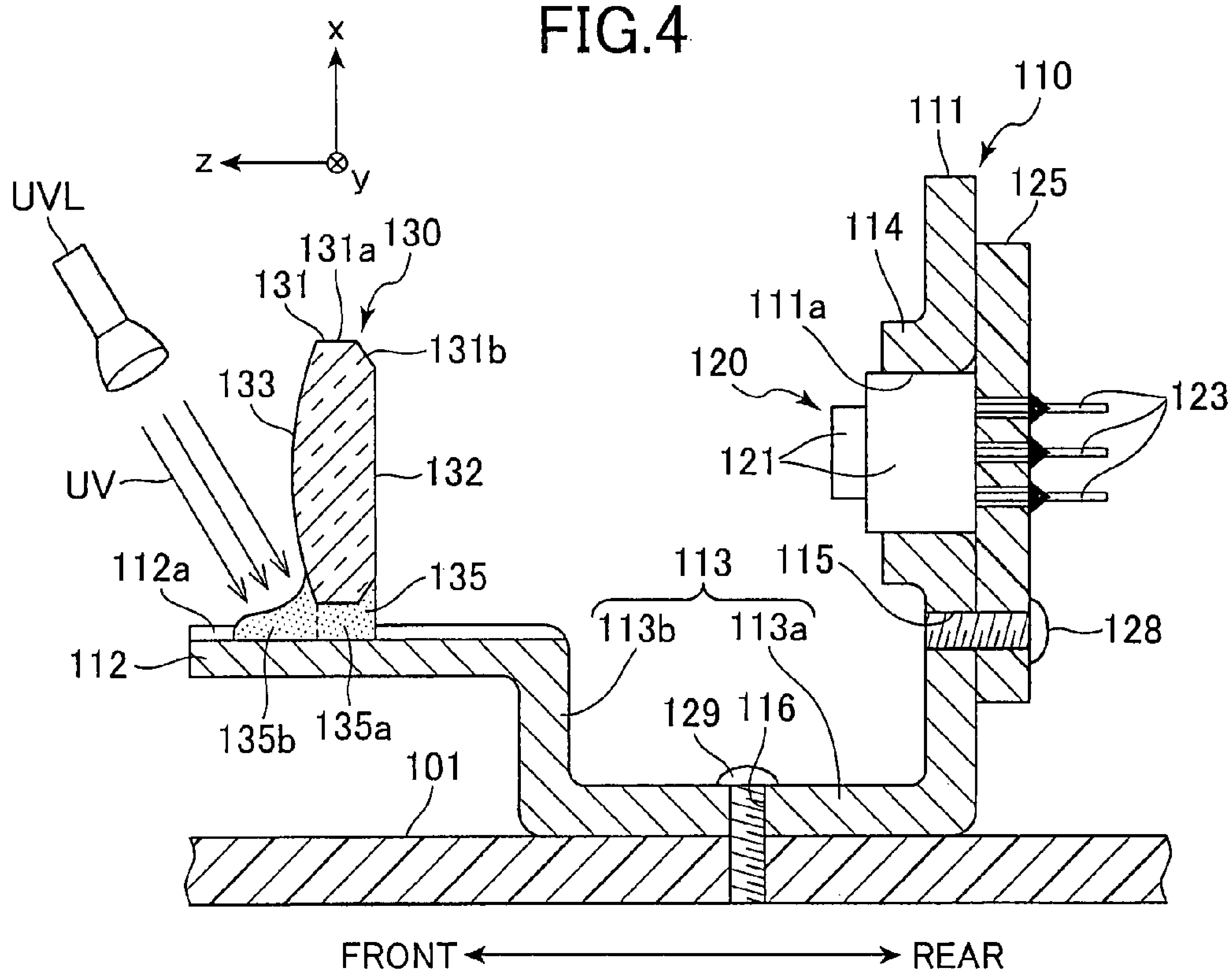
113a
113
REAR
FRONT

FIG.4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101
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FIG.5

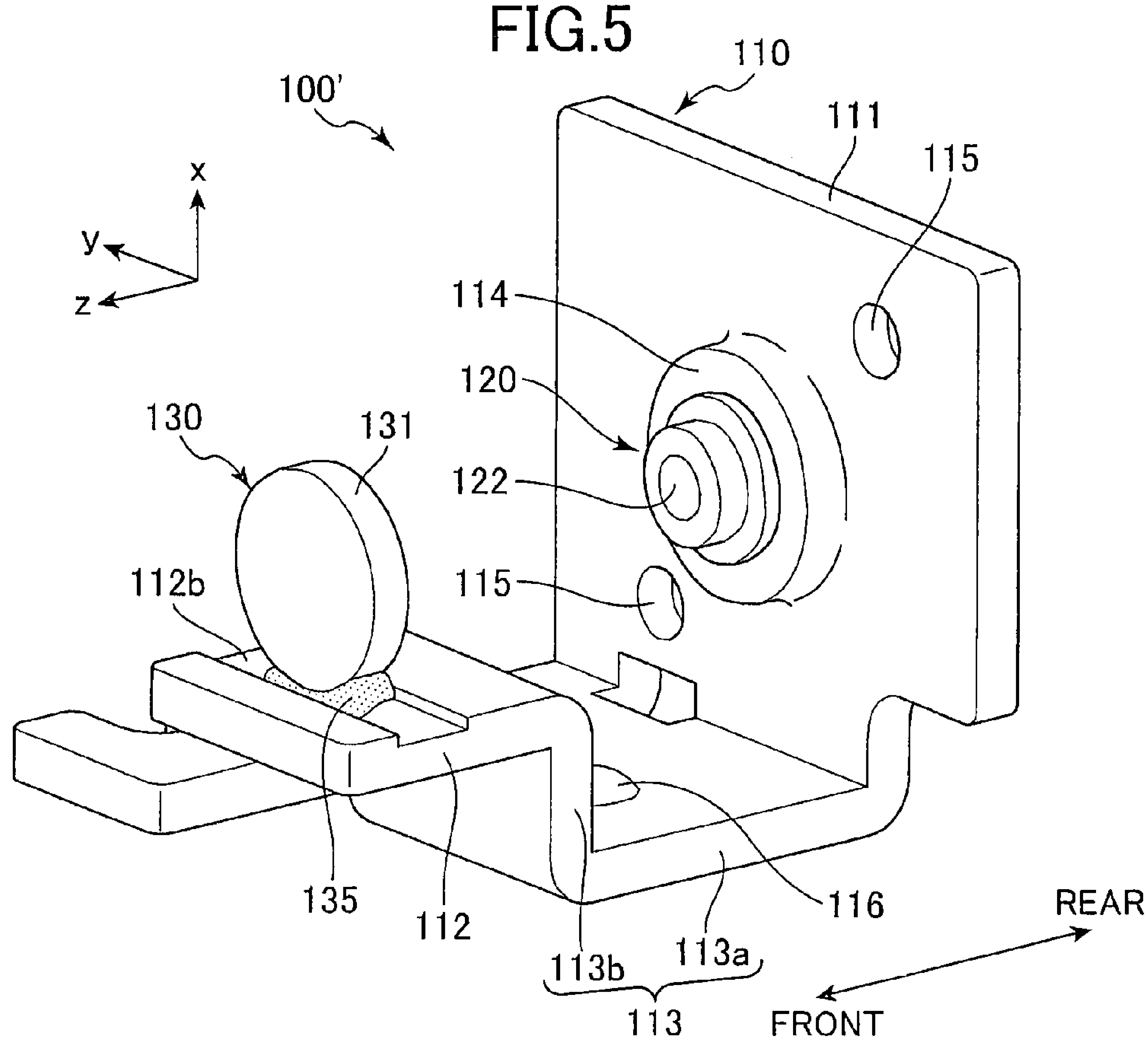
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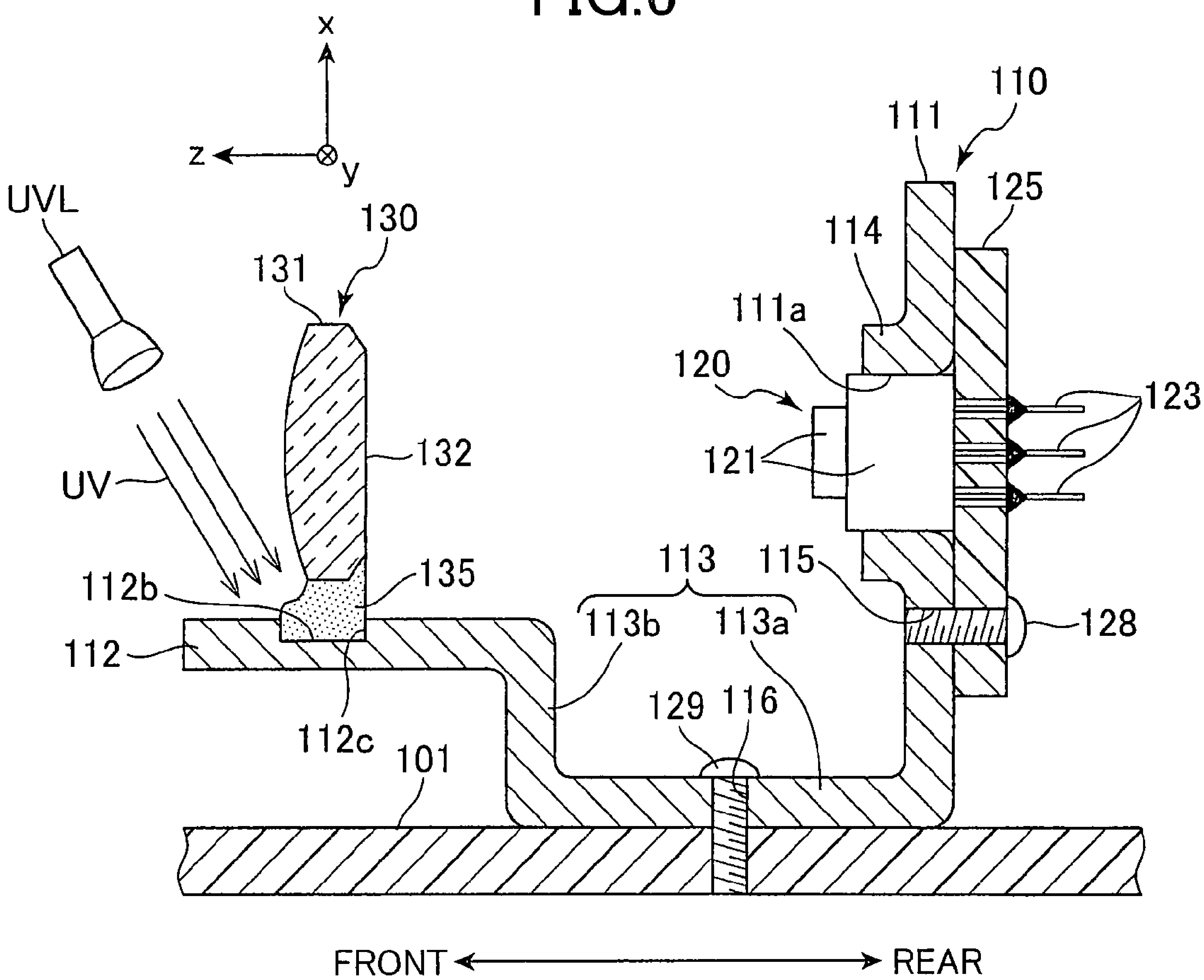
FIG.6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120
121
123
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REAR

LIGHT SOURCE DEVICE AND MANUFACTURING METHOD THEREOF

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority from Japanese Patent Application No. 2006-227130 filed Aug. 23, 2006. The entire content of this priority application is incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a light source device and a manufacturing method thereof, as well as an exposure device and an image forming device using the light source device.

BACKGROUND

In an image forming device such as a laser printer and a digital copier, a laser beam scans a photosensitive body in correspondence with data of an image to be printed. Thereby an electrostatic latent image is formed on the photosensitive body. Then, the image forming device forms an image by supplying developer to the electrostatic latent image, transferring the image to a recording sheet and fixing the image on the sheet.

The image forming device is required to be downsized and low-priced in recent years. In accordance therewith, a light source device that irradiates the laser beam for forming the electrostatic latent image is also required to have a small size and a simple structure, while high accuracy in a product is also required.

The light source device includes a semiconductor laser and a coupling lens (or also called a collimating lens) that gathers the laser light emitted from the semiconductor laser and converts the laser light to a light flux. These two members are positioned with their optical axes being aligned with each other with high accuracy.

Japanese Patent Application Laid-Open Publication No. Hei-11-231237 (which will be referred to as Document 1 hereinafter) discloses, in its FIG. **1**, a light source device in which a laser holder that holds a semiconductor laser and a lens holder that holds a coupling lens are prepared separately. The semiconductor laser and the coupling lens are fixed on the respective holders, and the holders are fixed after being positioned corresponding to each other. The lens holder is formed in a cylindrical shape so as to surround the whole circumference of the lens.

Japanese Patent Application Laid-Open Publication No. 2002-31773 (which will be referred to as Document 2 hereinafter) discloses, in its FIG. **2**, another light source device that has a more simplified configuration in comparison with the configuration described above. The light source device described in Document 2 uses a holder (holding member) that is formed by integrating a part (main part) for holding the semiconductor laser and a part for holding the coupling lens. The part for holding the coupling lens is in a base shape that protrudes from the main part of the holder in front thereof. After the semiconductor laser is fixed on the holder, the coupling lens is fixed with photopolymerizable or light-curing resin on the base portion of the holder in front of the semiconductor laser. It is noted that the photopolymerizable resin is provided not only between the coupling lens and the base, but also a part of the photopolymerizable resin protrudes outside from between the coupling lens and the base both on the front and rear sides of the coupling lens. Japanese Patent Application Laid-Open Publication No. Hei-9-218368 (which will be referred to as Document 3 hereinafter) discloses, in its FIG. **1**, a case where the photopolymerizable resin is provided only between the coupling lens and the base.

SUMMARY

When the coupling lens is relatively thick, the lens can be sufficiently fixed by a method in which the photopolymerizable resin is provided only between the coupling lens and the holder as proposed in Document 3.

In addition, when the coupling lens is relatively thin, the lens can be fixed firmly by bonding the lens with the base not only at an outer peripheral surface of the lens, but also at the front and rear surfaces of the lens in a manner that a part of the photopolymerizable resin protrudes out from between the peripheral surface of the lens and the holder to the front and rear sides of the lens. It is noted that the front surface of the lens is defined as the surface of the lens from which the laser light exits, while the rear surface of the lens is defined as the other surface of the lens into which the laser light enters.

When the coupling lens is fixed on the base-shaped part of the holder as described in Document 2, the lens needs to be held in air by a robot hand with respect to the base. Therefore, irradiating an a curing light, such as an ultraviolet ray, for curing the photopolymerizable resin from directly above the coupling lens is difficult. However, if the ultraviolet ray is irradiated from the front (a side where the laser light exits) of the coupling lens, the ultraviolet ray does not strike on the part of the photopolymerizable resin that protrudes to the rear side of the coupling lens due to refraction of the light at the lens. For this reason, there is a problem that the photopolymerizable resin is not cured, or a large amount of time is required for the curing.

In such a case where the photopolymerizable resin cannot be cured evenly at a time, there is a possibility that the coupling lens moves due to contraction of the photopolymerizable resin while the photopolymerizable resin cures. Thereby, accuracy of the light source device may be lowered.

In view of the above, an object of the present invention is to provide a light source device with simple structure and high accuracy and a manufacturing method thereof, and an exposure device and an image forming device that employ the light source device.

In order to attain the above and other objects, the invention provides a light source device, including: a semiconductor laser; a coupling lens; a holder; and a photopolymerizable resin. The coupling lens converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side. The holder holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser. A part of the photopolymerizable resin is provided between the outer peripheral surface of the coupling lens and the holder and another remaining part of the photopolymerizable resin protrudes from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, the photopolymerizable resin being cured to fix the coupling lens on the holder.

According to another aspect, the present invention provides an exposure device for forming an electrostatic latent image by scanning light on a photosensitive body, the exposure device including: a light source device that emits laser light; a cylindrical lens that focuses the laser light emitted from the light source device; a deflector that reflects the laser light that has passed through the cylindrical lens, thereby deflecting the laser light to scan in a main scanning direction; and a scanning lens that images on the photosensitive body the laser light that has been deflected to scan by the deflector. The light source device includes: a semiconductor laser; a coupling lens that converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side; a holder that holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser; and a photopolymerizable resin, a part of the photopolymerizable resin being provided between the outer peripheral surface of the coupling lens and the holder and another remaining part of the photopolymerizable resin protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, the photopolymerizable resin being cured to fix the coupling lens on the holder.

According to another aspect, the present invention provides an image forming device for forming an image on a recording sheet, the image forming device including: an exposure device that forms an electrostatic latent image by scanning light on a photosensitive body; the photosensitive body on which the electrostatic latent image is formed by the exposure device; a developing unit that supplies developer on the photosensitive body; and a transfer mender that transfers an image formed by the developer onto a recording sheet. The exposure device includes: a light source device that emits laser light; a cylindrical lens that focuses the laser light emitted from the light source device; a deflector that reflects the laser light that has passed through the cylindrical lens, thereby deflecting the laser light to scan in a main scanning direction, and a scanning lens that images on the photosensitive body the laser light that has been deflected to scan by the deflector, thereby forming an electrostatic latent image on the photosensitive body. The light source device includes: a semiconductor laser; a coupling lens that converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side; a holder that holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser; and a photopolymerizable resin, a part of the photopolymerizable resin being provided between the outer peripheral surface of the coupling lens and the holder and another remaining part of the photopolymerizable resin protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, the photopolymerizable resin being cured to fix the coupling lens on the holder.

According to another aspect, the present invention provides a method for manufacturing a light source device that includes a semiconductor laser, a coupling lens that converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, a holder that holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser, and a photopolymerizable resin that fixes the coupling lens on the holder, the method including: providing the photopolymerizable resin on a holder at its area that extends from a first position to a second position; locating a coupling lens, which has a first side and a second side opposite to the first side and an outer peripheral surface connecting the first side and the second side, on the photopolymerizable resin to allow the first position to be located between the holder and either one of the first side of the coupling lens and the outer peripheral surface of the coupling lens and to allow the second position to be located away from the second side of the coupling lens in a direction defined from the first side to the second side; and irradiating the photopolymerizable resin with a curing light for curing the photopolymerizable resin from a position that is away from the second side of the coupling lens in the direction defined from the first side to the second side.

BRIEF DESCRIPTION OF THE DRAWINGS

The particular features and advantages of the invention as well as other objects will become apparent from the following description taken in connection with the accompanying drawings, in which:

FIG. **1** is a cross-sectional side view of a laser printer according to an embodiment of the present invention;

FIG. **2** is a plan view of a scanner unit provided in the laser printer of FIG. **1**;

FIG. **3** is a perspective view of a light source device provided in the scanner unit of FIG. **2**;

FIG. **4** is a cross-sectional view of the light source device of FIG. **3**;

FIG. **5** is a perspective view of a light source device according to a modification; and

FIG. **6** is a cross-sectional view of the light source device of FIG. **5**.

DETAILED DESCRIPTION

A light source device, an exposure device and an image forming device according to an embodiment of the invention will be described while referring to the accompanying drawings wherein like parts and components are designated by the same reference numerals to avoid duplicating description.

FIG. **1** is a cross-sectional side view of a laser printer **1** according to the embodiment. FIG. **2** is a plan view of a scanner unit **16** provided in the laser printer **1**.

The laser printer **1** includes a main casing **2**. The laser printer **1** further includes: a feeder section **4** and an image forming section **5**. The feeder section **4** and the image forming section **5** are housed in the main casing **2**. The feeder section **4** supplies sheets **3** (recording medium) one sheet at a time to the image forming section **5**. The image forming section **5** forms a desired image on the supplied sheet **3** based on print data.

The feeder section **4** includes: a paper supply tray **6**, a paper pressing plate **7**, a sheet supply roller **8**, a separating pad **9**, paper dust removing rollers **10** and **11**, and registration rollers **12**. The paper supply tray **6** is detachably mounted in the bottom section of the main casing **2**. The paper pressing plate **7** is disposed inside the paper supply tray **6**.

In the feeder section **4**, a stack of sheets **3** mounted in the paper supply tray **6** are pressed against the sheet supply roller **8** by the paper pressing plate **7**. One sheet at a time is separated from the sheet stack by the sheet supply roller **8** and the separating pad **9**, and passes the various rollers **10-12**, before being conveyed to the image forming section **5**.

The image forming section **5** includes: the scanner unit **16**, a process cartridge **17**, and a fixing section **18**.

The scanner unit **16** is provided in an upper part of the main body casing **2**. As shown in FIG. **2**, the scanner unit **16** includes a light source device **100**, a cylindrical lens **25**, a polygon mirror **19**, an fθ lens **20**, and a reflecting mirror **22**. The light source device **100** is for emitting laser light modulated according to print data. The cylindrical lens **25** gathers or focuses laser light emitted from the light source device **100** in a sub-scanning direction, while guiding the laser light to fall incident on the polygon mirror **19**, thereby correcting an optical face tangle error of the polygon mirror **19**. The polygon mirror **19** has a mirror formed on each side of a hexagon. While rotating, the polygon mirror **19** reflects the laser light which has passed through the cylindrical lens **25**. Thereby, the mirror **19** deflects and scans the laser light in a main scanning direction. The fθ lens **20** converts the laser light which has been made to scan at an equal angular velocity by the polygon mirror **19** so that the laser light scans at a uniform velocity, while imaging the laser light on a surface of a photosensitive drum **27** to be described later.

In addition, the scanner unit **16** includes a correction lens **21**, reflecting mirrors **23** and **24**, as shown in FIG. **1**, that serve to direct the laser light, which has been directed toward a lower direction by the reflecting mirror **22**, to the photosensitive drum **27**.

Each of the members described above is appropriately mounted in a case **101**.

The configuration of the light source device **100** will be described more in detail later.

The process cartridge **17** is disposed below the scanner unit **16** in the main casing **2**, and can be detached from the main casing **2**. The process cartridge **17** includes a casing **51**, in which the process cartridge **17** has a development cartridge **28**, the photosensitive drum **27**, a scorotron charge unit **29**, and a transfer roller **30**.

The development cartridge **28** is detachable from the casing **51**, and is provided with a developing roller **31**, a layer thickness regulating blade **32**, a supply roller **33**, and a toner box **34**.

The toner box **34** is filled with toner with a positively charging nature. Rotation of the supply roller **33** supplies the developing roller **31** with toner from the toner box **34**. At this time, the toner is triboelectrically charged to a positive charge between the supply roller **33** and the developing roller **31**. Then, as the developing roller **31** rotates, the toner supplied onto the developing roller **31** moves between the developing roller **31** and the layer thickness regulating blade **32**. This further triboelectrically charges the toner, and reduces thickness of the toner on the surface of the developing roller **31** down to a thin layer of uniform thickness.

The photosensitive drum **27** is disposed in confrontation with the developing roller **31**. The photosensitive drum **27** is supported rotatably in the casing **51**. The photosensitive drum **27** includes a drum-shaped member and a surface layer. The drum-shaped member is electrically grounded. The surface layer is formed from a photosensitive layer that is made from polycarbonate and that has a positively charging nature.

The scorotoron charge unit **29** is disposed above the photosensitive drum **27** and is spaced away from the photosensitive drum **27** by a predetermined space so as to avoid direct contact with the photosensitive drum **27**. The scorotron charge unit **29** is a positive-charge scorotron type charge unit for generating a corona discharge from a charge wire made from, for example, tungsten. The scorotoron charge unit **29** forms a blanket of positive-polarity charge on the surface of the photosensitive drum **27**.

The transfer roller **30** is rotatably supported at a position below and in confrontation with the photosensitive drum **27**. The transfer roller **30** is rotatably supported in the casing **51**. The transfer roller **30** includes a metal roller shaft and a roller portion covering the roller shaft. The roller portion is made from conductive rubber material. In order to perform a transfer operation, the transfer roller **30** is applied with a transfer bias according to a constant current control.

As the photosensitive drum **27** rotates, the scorotoron charge unit **29** first forms a blanket of positive charge on the surface of the photosensitive drum **27**, and then the surface of the photosensitive drum **27** is exposed to high speed scan of the laser beam from the scanner unit **16**. The electric potential of the positively charged surface of the photosensitive drum **27** drops at positions exposed to the laser beam. As a result, an electrostatic latent image is formed on the photosensitive drum **27** based on print data.

Next, an inverse developing process is performed. That is, as the developing roller **31** rotates, the positively-charged toner borne on the surface of the developing roller **31** is brought into contact with the photosensitive drum **27**. Because a developing bias voltage is applied to the developing roller **31**, the toner on the developing roller **31** is supplied to lower-potential areas of is the electrostatic latent image on the photosensitive drum **27**. As a result, the toner is selectively borne on the photosensitive drum **27** so that the electrostatic latent image is developed into a visible toner image.

The visible toner image borne on the surface of the photosensitive drum **27** confronts the transfer roller **30** and is transferred onto a sheet **3** as the sheet **3** passes between the photosensitive drum **27** and the transfer roller **30**.

The fixing section **18** includes a heating roller **41**, a pressure roller **42** applying pressure to the heating roller **41**, and transport rollers **43**. In the fixing section **18**, the toner, which has been transferred to the sheet **3** by the process cartridge **17**, is thermally transferred onto the sheet **3** while the sheet **3** passes through between the heating roller **41** and the pressure roller **42**. Thereafter, the sheet **3** is transferred to a sheet discharging path **44** by the transport rollers **43**. The sheet **3** transported to the sheet discharging path **44** is conveyed to discharge rollers **45**. When the discharge rollers **45** rotate forwardly, the discharge rollers **45** discharge the sheet **3** onto a discharge tray **46**. When the discharge rollers **45** rotate in reverse and a flapper **49** is swung from the orientation shown in solid line to the orientation shown in broken line in FIG. **3**, the sheet **3** is fed back to the inside of the main casing **2** and is fed back to the upstream side of the image forming section **5** by a plurality of inversion transport rollers **50**. At this time, the upper and lower surfaces of the sheet **3** are reversed from the first time that an image has been formed on the sheet **3** so that an image can be formed on the other side as well. In this way, images are formed on both sides of the sheet **3**.

FIG. **3** is a perspective view of the light source device **100**. FIG. **4** is a cross-sectional view of the light source device **100**.

As shown in FIG. **3**, the light source device **100** includes a holder **110**. A semiconductor laser **120** and a coupling lens **130** are fixed on the holder **110**. The semiconductor laser **120** is for emitting light that is modulated according to the print data.

The holder **110** is obtained by carrying out a sheet-metal processing on a plate material made of aluminum alloy or aluminum.

The holder **110** includes a laser holding wall **111**, a lens holding part **112**, and a connecting part **113**. The semiconductor laser **120** is fixed on the laser holding wall **111**. The lens holding part **112** is of a base shape, and the coupling lens **130** is fixed on the base-shaped lens holding part **112**. The connecting part **113** connects the laser holding wall **111** and the lens holding part **112** with each other.

The laser holding wall **111** has a mounting through-hole **111***a* having a circular shape. The mounting through-hole **111***a* is formed on the center of the laser holding wall **111**. The mounting through-hole **111***a* is formed by penetrating the laser holding wall **111** so that the semiconductor laser **120** can fit therein (refer to FIG. **4**). An edging **114** projecting toward a front side (direction in which the laser light of the semiconductor laser **120** is emitted) is formed on an edge of the mounting through-hole **111***a*. The edging **114** forms a tube part, in which the semiconductor laser **120** fits. In addition, the laser holding wall **111** has two screw through-holes **115** provided thereon. The screw through-holes **115** are used for fixing the semiconductor laser **120** (refer to FIG. **3**) on the laser holding wall **111**.

The lens holding part **112** is located distant from the laser holding wall **111** for a predetermined distance in a front direction. A groove **112***a* extending in a front-back direction is formed on a top surface of the lens holding part **112**, that is, a surface on which the coupling lens **130** is mounted. Photopolymerizable or light-curing resin **135** that serves as adhesive for fixing the coupling lens **130** on the lens holding part **112** is provided in the groove **112***a*. That is, by applying the photopolymerizable resin **135** in the groove **112***a* in a manner that the resin **135** stays in the groove **112***a*, the resin is prevented from flowing away from the lens **130** in a direction perpendicular to the front-back direction. The groove **112***a* can also serve as a reference position, on which the photopolymerizable resin **135** is to be applied.

The holder **110** is preferably made of metal. For example, the holder **110** is made of aluminum or aluminum alloy. In this manner, a top surface of the lens holding part **112** is capable of reflecting light for curing the photopolymerizable resin **135**. By reflecting light on the surface of the lens holding part **112**, the curing of the photopolymerizable resin **135** can be accelerated. The holder **110** may be made of other material that can reflect off light.

The connection part **113** includes a bottom wall part **113***a* and a front wall part **113***b*. The bottom wall part **113***a* extends in a front direction from a bottom edge of the laser holding wall **111**. The front wall part **113***b* extends vertically so as to connect a front edge of the bottom wall part **113***a* and a rear edge of the lens holding part **112**. The bottom wall part **113***a* has a screw through-hole **116** formed thereon. The screw through-hole **116** is used for fixing the holder **110** on the case **101** of the scanner unit **16**.

The semiconductor laser **120** is a known device including a package **121** as an outer packaging and an aperture **122** formed on the package **121**. A light emitting element (not shown) is provided in the inside of the package **121**. The laser light is emitted from the semiconductor laser **120** through the aperture **122**. As shown in FIG. **4**, the semiconductor laser **120** is pressed and fixed in the mounting through-hole **111***a*. The semiconductor laser **120** has terminals **123**. The terminals **123** pass through through-holes formed in a printed circuit board **125** and are connected to a circuit (not shown). The print circuit board **125** is fixed to the laser holding wall **111** by fastening screws **12**B in the screw through-holes **115**.

The coupling lens **130** is for gathering the laser light emitted from the semiconductor laser **120** and converts the laser light to a light flux (bundle of light). The coupling lens **130** is located distant from the semiconductor laser **120** by a distance that is determined dependently on a focal length of the lens **130**. The coupling lens **130** is bonded with and fixed on the lens holding part **112** by the photopolymerizable resin **135**.

The photopolymerizable resin **135** is provided between the coupling lens **130** and the holder **110**, or more particularly, between the coupling lens **130** and the lens holding part **112**. A part of the photopolymerizable resin **135** protrudes from between the coupling lens **130** and the lens holding part **112** to the front side of the coupling lens **130**. However, no part of the photopolymerizable resin **130** protrudes from between the coupling lens **130** and the lens holding part **112** to a rear side of the coupling lens **130**. That is, no photopolymerizable resin **130** is provided on the rear side of a rear surface **132** of the coupling lens **130**.

In other words, the photopolymerizable resin **135** is provided on the lens holding part **112** so that the photopolymerizable resin **135** has a main part **135***a* that is located between the coupling lens **130** and the lens holding part **112** and a front protruding part **135***b* that protrudes forwardly from the main part **135***a*.

More specifically, the coupling lens **130** has a pair of optical surfaces **132** and **133** and an outer peripheral surface **131**. The pair of optical surfaces **132** and **133** includes: the rear surface **132** and a front surface **133**. The laser light from the semiconductor laser **120** passes through the pair of optical surfaces **132** and **133**. The outer peripheral surface **131** connects the pair of optical surfaces **132** and **133**. In this example, the outer peripheral surface **131** has: a main part **3131***a* that extends parallel to the optical axis of the coupling lens **130** and an additional part **131***b* that extends from the main part **131***a* toward the rear surface **132** obliquely rearwardly with respect to the optical axis of the coupling lens **130**. The rear surface **132** is flat and is perpendicular to the optical axis of the coupling lens **130**, while the front surface **133** is curved around the optical axis of the coupling lens **130**

In the photopolymerizable resin **135**, the main part **135***a* is located between the outer peripheral surface **131** of the coupling lens **130** and the lens holding part **112**, while the front protruding part **135***b* protrudes forwardly from the main part **135***a*. No part of the photopolymerizable resin **130** protrudes rearwardly from the main part **135***a*.

As apparent from FIG. **4**, the coupling lens **130** is fixed at a position away from the lens holding part **112** in the vertical direction (x direction). In this manner, the coupling lens **130** can be fixed on the holder **110** after the position of the lens **130** is adjusted relative to the semiconductor laser **120**.

The coupling lens **130** can be made of glass or resin. A material having a thermal expansion coefficient, which is in a range of (½)×C to C, wherein C is the thermal expansion coefficient of a member constituting the holder **110** is preferably selected. By selecting a material having the thermal expansion coefficient close to that of the holder **110** as described above, a change in an optical characteristic of the light source device **100** can be made small even when there is a temperature change.

For example, in a case where aluminum having a thermal expansion coefficient αH of 2.30×10^{-5}/K is selected as the material of the holder **110** and glass having a thermal expansion coefficient αL of 1.15×10^{-5}/K is selected as the material of the coupling lens **130**, a tilt α a of an optical axis due to a temperature rise of 25 degrees Celsius (=ΔT) is calculated as:

$$\Delta a = a \tan((\alpha H - \alpha L)\times R \times \Delta T/f) = 0.47'$$

wherein R indicates a radius R of the lens **130** (3 mm, for example), and f indicates a focal length of the lens **130** (6.25 mm, for example).

It is noted that generally, adjustment accuracy of the lens of the light source device **100** is required to be ±5' Therefore, by selecting glass with material as described above, influence of a temperature rise can be restricted to be sufficiently small. An example of the glass, whose thermal expansion coefficient is in a range between a half of that of aluminum and that of aluminum, is "Super Vidron" (trade name) that has thermal expansion coefficient $\alpha L=11.8\times10^{-5}$/K and that is a molded glass manufactured by Sumita optical glass, Inc.

In addition, the outer peripheral surface **131** of the coupling lens **130** is roughened. So, when the coupling lens **130** is made of glass, the outer peripheral surface **131** is in a ground glass form. When the coupling lens **130** is made of resin, the outer peripheral surface **131** is in a ground resin form. Since the outer peripheral surface **131** is roughened, curing light (ultraviolet ray in the present embodiment) entering inside the coupling lens **130** diffuses adequately on the outer peripheral surface **131**. In this manner, the ultraviolet ray falls on the photopolymerizable resin **135** evenly below the coupling lens **130** (between the coupling lens **130** and the holder **110**).

The holder **110** is fixed on the case **101** in a manner that a screw **129** is put into the screw through-hole **116** and screwed in the case **101**.

With the above-described structure, the coupling lens **130** is fixed on the holder **110** by irradiating an ultraviolet ray UV from the front side of the coupling lens **130**. Therefore, the light source device **100** can be manufactured at low cost.

The photopolymerizable resin **135** is entirely cured at a time. In this manner, the coupling lens **130** can be positioned with high accuracy.

In addition, the photopolymerizable resin **135** is cured not only at a position between the outer peripheral surface of the coupling lens **130** and the lens holding part **112** but also at a position between the front side of the coupling lens **130** and the lens holding part **112**. In this manner, even in a case where the coupling lens **130** is relatively thin, the lens **130** can be fixed on the holder **110** firmly.

The light source device **100** can be configured at extremely low cost by configuring the holder **110** by carrying out the sheet metal processing on a metal plate. In particular, by adopting aluminum or aluminum alloy as the material of the holder **110**, heat dissipation of the holder **110** becomes higher. Thereby, the holder **110** can be made to have a function also as a cooling plate of the semiconductor laser **120**.

Next, a manufacturing method of the light source device **100** will be described.

First, the semiconductor laser **120** is pressed and fixed in the laser holding wall **111**. Then, the print circuit board **125** is fixed on the laser holding wall **111** with the screws **128**.

Then, the holder **110** is fixed on the case **101** of the scanner unit **16** with the screw **129**.

Next, the photopolymerizable resin **135** is applied on the groove **112***a* of the lens holding part **112**. The photopolymerizable resin **135** is applied to spread from a position, directly below a position where the coupling lens **130** is assumed to be located, to a slightly front side thereof. In this manner, when the coupling lens **130** is located on the lens holding part **112**, the photopolymerizable resin **135** is prevented from protruding out from the position between the coupling lens **130** and the lens holding part **112** to the rear side (side closer to the semiconductor laser **120**) of the coupling lens **130**. In this state, the photopolymerizable resin **135** is located between the coupling lens **130** and the lens holding part **112**, with partly protruding to the front side (exit side of the laser light) of the coupling lens **130**.

More specifically, the photopolymerizable resin **135** is applied to spread from a position, directly below a position where the outer peripheral surface **131** of the coupling lens **130** is assumed to be located, to a slightly front side thereof. In this manner, when the coupling lens **130** is located on the lens holding part **112**, the photopolymerizable resin **135** is prevented from protruding out from the position between the outer peripheral surface **131** of the coupling lens **130** and the lens holding part **112** to the rear side of the coupling lens **130**. In this state, the photopolymerizable resin **135** is located between the outer peripheral surface of the coupling lens **130** and the lens holding part **112**, with partly protruding to the front side of the coupling lens **130**.

Next, the coupling lens **130** is held by a robot hand (not shown) having multiple spindles. The coupling lens **130** may be held by the robot hand in a manner that the outer peripheral surface **131** of the coupling lens **130** is held or nipped by the robot hand, or the outer peripheral surface **131** or a rim of the front or rear side surface (optical surface) **133**, **132** of the coupling lens **130** is vacuum-absorbed by the robot hand. Then, the laser light is emitted from the semiconductor laser **120**. While tilt and a focus of the laser light which has passed through the coupling lens **130** are checked by a measuring unit or visual observation, the robot hand is operated to adjust orientation and a position in the x-y direction shown in FIG. **3** or FIG. **4** of the coupling lens **130**. Further, in a similar manner, a position in the z direction shown in FIG. **3** or FIG. **4** of the coupling lens **130** is adjusted.

Then, after the position of the coupling lens **130** is fixed, an ultraviolet ray lamp UVL is provided in the front side of the coupling lens **130**. By irradiating the ultraviolet ray UV on the photopolymerizable resin **135** from the front side, the photopolymerizable resin **135** is cured. The ultraviolet ray UV is irradiated from the front side of the coupling lens **130**. Or, the ultraviolet ray UV may be irradiated obliquely from an upper front side of the coupling lens **130** so that the ultraviolet ray UV strikes on the photopolymerizable resin **135** entirely.

By the operation described above, the coupling lens **130** can be fixed on an ideal position with respect to the semiconductor laser **120**. In particular, the photopolymerizable resin **135** is entirely cured by the ultraviolet ray UV that is entirely struck on the photopolymerizable resin **135** even when the ultraviolet ray UV is irradiated from the front side of the coupling lens **130**. This is because the photopolymerizable resin **135** is provided between the coupling lens **135** and the holder **110** and partly protrudes on the front side of the coupling lens **130**. In addition, as described above, the ultraviolet ray UV which has entered inside the coupling lens **130** is diffused on the outer peripheral surface **131**. Then, the ultraviolet ray UV also strikes on the photopolymerizable resin **135** between the coupling lens **130** and the holder **110** evenly. In this manner, an uncured part can be eliminated. Further, the ultraviolet ray UV which has passed through the photopolymerizable resin **135** reflects off the surface of the holder **110**, or more particularly, the lens holding part **112**, and contributes to the curing of the photopolymerizable resin **135** again. Therefore, the photopolymerizable resin **135** can be prevented from being uncured.

Thus, the coupling lens **130** is firmly fixed on the holder **110**. In addition, the photopolymerizable resin **135** is cured at a time. So, accuracy of positioning of the coupling lens **130** can be improved.

Irradiating the ultraviolet ray from the rear side of the coupling lens **130** is difficult due to existence of the laser holding wall **111**. However, according to the manufacturing method of the present embodiment, the ultraviolet ray does not need to be irradiated from the rear side of the coupling lens **130**, and the light source device **100** can be manufactured easily. By irradiating the ultraviolet ray from the front side of the coupling lens **130**, the ultraviolet ray can be irradiated on the photopolymerizable resin **135** entirely without the coupling lens **130** blocking the light.

<Modifications>

For example, FIG. **5** is a perspective view of a light source device **100'** according to a modification. FIG. **6** is a cross-sectional view of the light source device **100'**.

As shown in FIG. **5**, a light source device **100'** has a groove **112***b* formed on the lens holding part **112** of the holder **110** along a direction (y direction in FIG. **5** or FIG. **6**) perpendicular to the front-back direction of the coupling lens **130**. The groove **112***b* has an edge part **112***c* as a rear edge thereof which is positioned at the same position or slightly in front of the rear surface **132** of the coupling lens **130** along the front-back direction (z direction).

By providing the transverse groove **112***b* as described above on the lens holding part **112**, the photopolymerizable resin **135** is prevented from protruding out to the rear side of the coupling lens **130** when the photopolymerizable resin **135** is applied on the groove **112***b*. For this reason, the photopolymerizable resin **135** can be applied between the coupling lens **130** and the holder **110**, and easily protrudes out only to the front side of the coupling lens **130**.

In addition, in the embodiment described above, the robot hand is used to adjust the position and the orientation of the coupling lens **130**. However, the position and the orientation of the coupling lens **130** may be adjusted manually while the coupling lens **130** is held by a goniometer.

While the invention has been described in detail with reference to the embodiment and modification thereof, it would be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit of the invention.

For example, he laser printer **1** in the embodiment described above may be modified to other various types of image forming device, such as a copier and a multi-function machine.

The transfer roller **30** in the above embodiment may be modified into a non-contact type transfer roller.

In the above embodiment, the paper **3** such as a cardboard, a postcard, and a thin paper, is used as the recording sheet. However, the laser printer **1** may be modified to print on other various types of recording medium, such as an OHP sheet.

In the embodiment described above, the toner, the developing cartridge **28**, the polygon mirror **19**, the fθ lens **20**, the scanner unit **16**, and the photosensitive drum **27** are used as a developer, a developing unit, a deflector, a scanning lens, an exposure device, and a photosensitive body, respectively. However, the materials and the structure of the laser printer **1**, such as the developing cartridge **28**, the polygon mirror **19**, the fθ lens **20**, the scanner unit **16**, and the photosensitive drum **27**, can be appropriately modified.

What is claimed is:

1. A light source device, comprising:

a semiconductor laser;

a coupling lens that converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side;

a holder that holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser; and

a photopolymerizable resin, a part of the photopolymerizable resin being provided between the outer peripheral surface of the coupling lens and the holder and the entire remaining part of the photopolymerizable resin protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, such that no part of the photopolymerizable resin is protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the second side to the first side, the photopolymerizable resin being cured to fix the coupling lens on the holder.

2. The light source device according to claim **1**, wherein the holder is formed with a groove, on which the photopolymerizable resin is provided.

3. The light source device according to claim **2**, wherein the holder has a groove wall that defines the groove and that extends perpendicularly to the direction defined from the first side to the second side, the coupling lens being located with its first side being in alignment with the groove wall.

4. The light source device according to claim **2**, wherein the holder has a groove wall that defines the groove and that extends perpendicularly to the direction defined from the first side to the second side, the coupling lens being located with its first side being shifted from the groove wall in a direction defined from the second side to the first side.

5. The light source device according to claim **1**, wherein the holder is made of either one of aluminum and aluminum alloy.

6. The light source device according to claim **1**, wherein the coupling lens has a thermal expansion coefficient whose value is in a range of (½)×C to C, where C indicates a thermal expansion coefficient of a material configuring the holder.

7. The light source device according to claim **1**, wherein the holder is obtained made of a metal plate.

8. The light source device according to claim **1**, wherein the outer peripheral surface of the coupling lens is a roughened surface.

9. The light source device according to claim **1**, wherein the holder is made of metal having a light reflecting surface.

10. An exposure device for forming an electrostatic latent image by scanning light on a photosensitive body, the exposure device comprising:

a light source device that emits laser light, the light source device, comprising:

a semiconductor laser;

a coupling lens that converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side;

a holder that holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser; and

a photopolymerizable resin, a part of the photopolymerizable resin being provided between the outer peripheral surface of the coupling lens and the holder and the entire remaining part of the photopolymerizable resin protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, such that no part of the photopolymerizable resin is protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the second side to the first side, the photopolymerizable resin being cured to fix the coupling lens on the holder;

a cylindrical lens that focuses the laser light emitted from the light source device;

a deflector that reflects the laser light that has passed through the cylindrical lens, thereby deflecting the laser light to scan in a main scanning direction; and

a scanning lens that images on the photosensitive body the laser light that has been deflected to scan by the deflector.

11. An image forming device for forming an image on a recording sheet, the image forming device comprising:

an exposure device that forms an electrostatic latent image by scanning light on a photosensitive body, the exposure device comprising:

a light source device that emits laser light, the light source device, comprising:

a semiconductor laser;

a coupling lens that converts laser light from the semiconductor laser to a light flux, the coupling lens having a first side and a second side opposite to the first side, the coupling lens having an outer peripheral surface connecting the first side and the second side;

a holder that holds the semiconductor laser and the coupling lens in a manner that the first side of the coupling lens confronts the semiconductor laser; and

a photopolymerizable resin, a part of the photopolymerizable resin being provided between the outer peripheral surface of the coupling lens and the holder and the entire remaining part of the photopolymerizable resin protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the first side to the second side, such that no part of the photopolymerizable resin is protruding from between the outer peripheral surface of the coupling lens and the holder in a direction defined from the second side to the first side, the photopolymerizable resin being cured to fix the coupling lens on the holder;

a cylindrical lens that focuses the laser light emitted from the light source device;

a deflector that reflects the laser light that has passed through the cylindrical lens, thereby deflecting the laser light to scan in a main scanning direction; and

a scanning lens that images on the photosensitive body the laser light that has been deflected to scan by the deflector, thereby forming an electrostatic latent image on the photosensitive body;

the photosensitive body on which the electrostatic latent image is formed by the exposure device;

a developing unit that supplies developer on the photosensitive body; and

a transfer member that transfers an image formed by the developer onto a recording sheet.

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